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RESEARCH ARTICLE

Bias-corrected climate change projections over the Upper Indus Basin using a multi-model ensemble

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Abstract

The study projects climate over the Upper Indus Basin (UIB), covering geographic areas in India, Pakistan, Afghanistan, and China, under the two Representative Concentration Pathways (RCPs), viz., RCP4.5 and RCP8.5 by the late twenty-first century using the best-fit climate model validated against the climate observations from eight meteorological stations. GFDL CM3 performed better than the other five evaluated climate models in simulating the climate of the UIB. The model bias was significantly reduced by the Aerts and Droogers statistical downscaling method, and the projections overall revealed a significant increase in temperature and a slight increase in precipitation across the UIB comprising of Jhelum, Chenab, and Indus sub-basins. According to RCP4.5 and RCP8.5, the temperature and precipitation in the Jhelum are projected to increase by 3 °C and 5.2 °C and 0.8% and 3.4% respectively by the late twenty-first century. The temperature and precipitation in the Chenab are projected to increase by 3.5 °C and 4.8 °C and 8% and 8.2% respectively by the late twenty-first century under the two scenarios. The temperature and precipitation in the Indus are projected to increase by 4.8 °C and 6.5 °C and 2.6% and 8.7% respectively by the late twenty-first century under RCP4.5 and RCP8.5 scenarios. The late twenty-first century projected climate would have significant impacts on various ecosystem services and products, irrigation and socio-hydrological regimes, and various dependent livelihoods. It is therefore hoped that the high-resolution climate projections would be useful for impact assessment studies to inform policymaking for climate action in the UIB.

Keywords Upper Indus · Downscaling · Climate model · Model ensemble · Climate projections

Introduction

The scarcity of meteorological observations in the Himalaya (Pellicciotti et al. 2012; Zaz et al. 2019) has made climate model projections the first choice for impact assessment studies in order to prepare robust climate action plans for climate change adaptation and mitigation (Khan and Koch 2018; Lutz et al. 2016). The inability of the coarse resolution Atmosphere–Ocean General Circulation Models (AOGCMs) to represent the sub-grid scale features and accurate reflection of the mesoscale processes has, however, resulted in considerable uncertainties in climate change projections (Knutti and Sedláček 2013). The situation is exacerbated by the complex topography in regions like the Himalaya (Dimri and Niyogi 2013). Consequently, it is necessary to reduce the uncertainty in the model output before using these models for impact assessment at a local scale (Anandhi et al. 2008). Coupled Model Intercomparison Project 5 (CMIP5) climate projections are considered reliable and closer to *in situ* measurements and as such have been widely used all over the world (Taylor and Stephenson 2011; Chaturvedi et al. 2012; Jiang et al. 2012; Miao et al. 2014; Aloysius et al. 2016; Ran et al. 2020; Xiong et al. 2021; Krishnan and Bhaskaran 2021). Climate change projections for India have mostly relied on the Coupled Model Intercomparison Project 3 (CMIP3) models (Chaturvedi et al. 2012). It has been reported that CMIP3 and CMIP5 model simulations for temperature-and precipitation-related extremes agree well with the observations at the continental and global scales (Tebaldi et al. 2006; Sillmann et al. 2013). Several other studies have utilized CMIP3 and CMIP5 models for climate projections over other regions (Vera and Silvestri 2009; Coppola and Giorgi 2010; Fan et al. 2010; Yang et al. 2012);

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